recognized. In general, a movement southward along the coast of an area of high pressure in summer means fresh northerly winds and high temperatures in the interior of the State, with brisk, westerly winds, laden with fog, on the coast.

A kite meteorograph at the station has been used frequently in the following way: A descent from the station to sea level can be made by the train, a distance of 8 miles, in fifty minutes. The meteorograph was attached near the top of an open canopied car, insuring a good circulation, and carried in this way a number of times through the fog. We make in this way a rough cross section of the fog.

In fig. 1, Plate I, is shown perhaps the most common type of fog. It may be of interest to compute roughly the weight of water vapor existing under such conditions. From a number of records, a fair average dew-point temperature is 51° F. (10.6° C.). It is estimated that an area 10 miles east and west and an equal distance north and south is covered with fog. The upper level of the fog may be taken as half a mile. If the fog were solidly packed, we could not be much in error if we estimated its bulk at 50 cubic miles.

There are, therefore, $5280^3 \times 50$ cubic feet of water vapor at a mean temperature of 51° F. A cubic foot of vapor at this temperature weighs 4.222 grains, and we therefore have as a gross weight 2,219,535 tons of 2,000 pounds each. But most generally the fog disappears between sea level and 1,200 to 1,500 feet altitude, and there are also wide swaths or channels fog free. The amount given above, therefore, would need to be cut in two, and a liberal estimate of the weight of the water vapor in a fog outside the Heads is 1,000,000 tons. This is carried through the Golden Gate by westerly winds, blowing 22 miles per hour, from 1 to 5 p. m.

For each square mile of surface there would be about 10,000 tons of water vapor and for each acre about 15.63 tons. This is equivalent to a rainfall of 0.14 inch.

In Waldo's Modern Meteorology[1] an example in the use of Hertz's graphical tables for following the changes in a given quantity of water vapor under varying conditions is given. With little change, the problem will apply in this case.

At San Francisco the mean actual pressure is 29.87 inches (758.7 mm.) and at Tamalpais 27.55 inches (699.8 mm.); the elevation of the latter station is 724 meters, and the former is practically at sea level.

With a pressure of 750 mm. and a temperature of 27° C. (80° F.), a given mass of air, half saturated, lifted upward under adiabatic conditions, will not change its initial 11 grams of water contents per kilogram, until at an elevation of 640 meters, when condensation would begin. At an elevation of 700 meters, the pressure being 687 mm., the temperature would be 19.3° C. (67° F.).

At 640 meters the dew-point would be 13.3° (56° F.) or 2.5° lower than the initial dew-point 15.8° (60° F.), the difference being due to the increased volume. At 1,000 meters the temperature would be 8.2° C. (49° F.), or at a rate of 0.51° C. decrease per 100 meters elevation.

It is pointed out, however, that in all theoretical values the assumption is made that the kilogram of mixed air and water vapor retains its mass unchanged, but this can not be the case with a mixture in free air performing a journey of any extent. It is also to be remembered that in the actual case before us the horizontal movements of the given mass would be of far more significance than the vertical movements.

In von Bezold's third paper on the Thermodynamics of the Atmosphere (see Mechanics of the Atmosphere, pp. 257–288), the effect of mixing different air masses is considered. If two masses of saturated air at 0° C. and 20° C., respectively, and at 700 mm. pressure are thoroughly mixed, the greatest amount of rainfall that can occur is 0.75 gram per kilogram of air and water vapor. The temperature of the mixture will be 11° C. (52° F.). The warmer mixture would have yielded the same amount of rainfall by raising it 310 meters or cooling it 1.6° C. by elevation and 0.8° C. by contact.

Direct cooling by contact or radiation is shown by von Bezold to be more efficient as a cause of rainfall than cooling by mixture, but in the production of fog it is probable that cooling by mixture (except in the case of ground fogs) is the most important factor to be considered. It is to be noted that reverse pressures should also be studied, for perhaps a close watch upon the conditions prevailing when fog is rapidly dissipating might conversely throw light upon the order and relative importance of the three ways of cooling, viz, mixture, expansion, and radiation.

Von Bezold's deductions may be thus summarized: More vapor condenses when a stream of air and vapor at low temperature impinges on a mass of warmer air than with reversed conditions. Ocean fogs as a rule form when cool air flows over warm, moist surfaces, but in the case under discussion, where the ocean surface temperature is 13° C. (55° F.) and the air temperature may reach 27° C. (80° F.), it is evident that the above does not hold. It is more probable that condensation is the result of the sharp temperature contrasts at the boundaries of certain air currents having different temperatures, humidities, and velocities, and that the contours of the land play an important part in originating and directing these air currents. The summer afternoon fogs of the San Francisco Bay region then are probably due to mixture, more than radiation or expansion. The winter tule fogs of the Sacramento and San Joaquin valleys are probably pure types of radiation fog, where the process of cloud building is from the cooled ground upward. Occasionally in summer, when the warm air has been pumped out of the valleys and there is rapid radiation, ground fog forms. An illustration of this is given in fig. 2, Plate I, where fog covers a number of valleys. Summer sea fog is shown in fig. 3, Plate II, and, as said above, is probably due to mixture. The wave motions or Luft Wogen of von Helmholtz are shown in fig. 4, Plate II, and also the surgings or splashings, where a certain condensation results from the mechanical uplifting.

THE WATER SUPPLY FOR THE SEASON OF 1900 AS DEPENDING ON SNOWFALL.

On November 9 the Chief of Bureau called for reports from the section directors for Colorado, Idaho, Montana, New Mexico, Utah, and Wyoming on the water supply of the last season, the value of snow data published in special snow bulletins, and the verification of any predictions based upon the experience of past seasons. The replies summarize the work done in the respective sections, and especially the data published in the special bulletins and the ice and snow charts of the Climate and Crop Division during the early spring of 1900. No better method of presenting this important subject to our readers could be desired than the publication of these excellent reports, which follow herewith. The importance of forecasting the supply available for irrigation was discussed by the Chief of Bureau and others at the Irrigation Congress held in November in Chicago.—ED.

COLORADO.

By F. H. BRANDENBURG, Section Director.

The Weather Bureau began the collection of snowfall statistics in Colorado four years ago, believing that it would be possible to forecast accurately the prospective volume of water in the streams, and that such information would be of material advantage to agricultural interests.

In the early days, when agricultural operations were necessarily limited, the flow during summer was of comparatively little moment, but with the increase of population agriculture

[1] Page 236. The paper in full is translated in Professor Abbe's Mechanics of the Earth's Atmosphere, No. XIV, pp. 198–211. [Improved methods are given by Professor Bigelow in his Report on the International Cloud Observations, Washington, 1900.—ED.]

made rapid progress, and to supply the demand large canals took the place of the small ditches which had been constructed here and there by a few farmers. Many of these canals possess a capacity equal to the entire flow of the streams supplying them, and vast areas were brought "under ditch," regardless of the fact that during midsummer a shortage might reasonably be expected. While agriculture by irrigation has reached a high state of development in Colorado—unrivaled elsewhere in the arid region—its further extension under existing conditions is impossible. The amount of water that reaches the streams during the summer season is undoubtedly smaller now than it was a quarter of a century ago, and, while greater economy in its use has become necessary, a scarcity is common, and droughty conditions during the summer months entail great loss. Deforestation and forest fires have removed large tracts of timber—nature's reservoirs in the mountains—so that the amount of moisture conserved till midsummer is rapidly growing less under the unobstructed action of the sun and winds. What is true of Colorado is, or soon will be, equally true of other mountain States of the arid region unless strenuous efforts are made to reforest the devastated areas and to protect the timber still standing. If, on account of close grazing during recent years, the run-off from the treeless plains is rapid as compared with years ago, when undisturbed vegetation conserved the moisture, is it unreasonable to expect a similar effect to follow the close grazing which is now common during summer in the upper parts of the catchment basins and during the entire year in the timber of moderate elevations?

A study of the snowfall data collected during recent years does not bear out the notion so prevalent in the arid region, i. e., that a winter of heavy snowfall is succeeded by a spring and a summer with copious and well-distributed precipitation. The data have also thrown light on the volume and duration of the flow to be expected. From the bare knowledge that there is an unusually large amount of snow in the mountains, we must not conclude that there will be an ample and prolonged flow. In illustration of this important fact, I shall briefly review the conditions that have recently obtained: During the closing months of 1898 the snowfall along the Continental Divide and adjacent regions in Colorado was greater than experienced for many years. January added 15 per cent and February a like amount, stormy weather having been almost continuous, with plenty of wind to sweep the snow into the gulches and ravines. March was even wetter than any of the four preceding months. As compared with the stupendous amounts that fell during that season, the winter of 1899–1900 was dry, especially during January and March, though October contributed a heavy fall, and February less than the normal amount for the region as a whole. It thus appears that the winters were notably different. The spring of 1899 was practically rainless, that of 1900 exceptionally wet. The summer of 1899 had slightly more than the normal precipitation, while the summer of 1900 was droughty. We now come to the water supply: the volume available during the spring and summer of 1899 was inadequate on the eastern slope, except for a brief period in June, notwithstanding the stupendous amount of snow that fell during the preceding winter. In 1900 irrigation enterprises fared better during spring and part of summer, despite the light snowfall of the preceding winter. The anomaly is explained by the fact that in consequence of the long, dry period which preceded the stormy winter of 1898–99, the ground was dry and unfrozen when the first snow fell, hence it absorbed a vast amount of moisture when melting began. The unusual dryness during spring played an important part for, as is usual in droughty times, high winds, desiccating in character, were almost continuous, honey-combing the snow and causing a large proportion to disappear as if by magic. When the winter of 1899–1900 set in the ground was well supplied with moisture and frozen, as a rule, so that in the spring, which was notably free from high winds, the run-off reached the streams with comparatively little loss and being augmented by seepage from the unprecedented fall of rain and melted snow during April (about ten inches) a satisfactory flow was maintained until about the middle of July. From this comparison it appears that the following considerations are important: Whether or not large amounts fall in autumn and early winter, the condition of the soil when winter sets in, the temperature during May and June, and the precipitation during summer, rather than the total snowfall of the winter, are the essential factors in determining the duration of a material flow.

In diverting water from those of the larger streams of the middle Rocky Mountain region that have their sources west of the Continental Divide, difficult problems in engineering are encountered, hence dependence must be placed on the small streams whose flow is likewise unfavorably affected by the conditions already mentioned.

Snowfall bulletins are regularly published at the close of December and monthly thereafter during the season. They contain data regarding the condition of the soil, whether wet or dry, free from frost or not, at the time stormy weather set in; the fall of snow compared with that of like period the preceding year; a comparison with the normal or average; the depth at timber line and above, together with a statement regarding the prospective flow. In the first bulletin of the past season, in addition to summarizing the conditions as reported, the prediction was made that the run-off from melting snow would be relatively great and rapid. In the January bulletin attention was called to the fact that the current fall scarcely made good the loss by evaporation; that for February contained the statement that as recent falls were loosely packed they were likely to go quickly, and that for March the forecast that the run-off from high elevations would not be as great as during the preceding year and cease much earlier. Full data regarding the phenomenally heavy fall of rain and snow over the eastern half of the State during April were promptly placed before interested persons, together with a statement regarding the heavy flow to be expected from the foothills during the early part of the season. It is gratifying to note that all conclusions of a predictive character were fully verified.

The bulletins have a wide circulation. Every post office in the State is furnished with a copy for display, and a large demand for copies comes from the residents of western Nebraska, western Kansas, New Mexico, and as far west as southern Nevada and Arizona.

It is evident that the conditions as regards protection to the snow in the mountains are not such as to conserve till late in the season anything near the amount of moisture needed to irrigate the extensive areas now under ditch. The results attained during recent years emphasize the fact that however stupendous the snowfall of winter, crops are sure to suffer during summer unless normal rainfall occurs.

IDAHO.

By S. M. BLANDFORD, Section Director.

In accordance with authority granted this office by the Chief of Bureau to issue special snow bulletins during the winter of 1900, three bulletins showing depth of snow in all parts of Idaho were issued on dates as follows: January 31, February 28, and March 31.

To secure uniformity and to allow of intelligent comparison, the bulletins were modeled after those previously issued by the Colorado section and represented the snowfall as compared with the average amount on ground, amount at timber line, depth at or near the summit of mountains, and prospective water flow.

It was ascertained through the information contained in the bulletins that nearly all the snow that fell in December, 1899, disappeared during January, 1900, through the prevalence of adiabatic conditions and exceptionally mild weather; nearly normal temperature conditions prevailed during February and the snowfall slightly increased in some sections, but rapidly disappeared during March, when the temperature was the highest for any March on record. The March bulletin disclosed the fact that the snowfall in the mountains had been decreasing since the latter part of December, 1899.

In the bulletin issued on the 31st of March, 1900, the conditions then existing were expressed as follows:

During the first decade of March light snow fell on the mountains to an appreciable depth, but the temperature having risen considerably above the normal on the 11th and continued mild throughout the month, resulted in lighter measurements of snow at the close of March than at any time since December 31, 1899. At the timber line the snow has decreased materially, and on the summit of the mountains the decrease was greater over the Snake River watershed than the Columbia. In agricultural districts there is practically no snow on the ground to obstruct farming operations and the ranges are open to the herdsman.

Since the estimates of depth of snow in the mountains range from a quarter to half the average, it is evident that the water flow will be considerably less than the average, and that the need for economy in the use of water will arise before midsummer.

The forecast was deduced from the measurements of snow in the mountains, assisted by the remarks of correspondents, which were generally to the effect that, within the memory of the oldest inhabitant, the mountain snow supply during the winter of 1899–1900 was the least ever known.

Value of special snow bulletins.—Immediately the first snow bulletin was issued to the public its value became evident. The newspapers considered the information of such interest as to publish extensive extracts, and the Idaho Daily Statesman published the first and each succeeding bulletin in full; many journals published the tabulated data in full. Those who appeared most eager to receive the bulletins were the mining men desiring to begin prospecting or placer mining. In this connection it was gratifying to this office to learn from mining men having extensive interests that the bulletins were of such value as to make individual efforts at collecting the same information through private correspondence unnecessary. The bulletins having been extensively distributed to stockmen, it was learned that they filled a long felt want. It appears that the southwestern valley sections of Idaho are especially desired by the sheep herders for wintering sheep, owing to the mildness of the climate. In the early spring bands of sheep begin to roam the prairies, keeping close to water. In the course of a season a band of sheep may travel from the Snake River to the Saw Tooth mountains and return, a distance of 400 to 600 miles or more, depending upon accessibility to water and grass. The snow bulletins enabled the stockman to ascertain the depth of snow on the high prairie lands and estimate the probable water supply.

Concerning predictive conclusions.—In the light of the experience during the past season it can be stated without hesitation that the forecasts of shortage of water were fully verified. In fact, all small streams had begun to recede by the close of May, and would have begun earlier, but for the occurrence of excessive precipitation during May. Large streams such as the Snake, Boise, and Payette rivers reached the lowest stage ever known, but continued to supply all the irrigation canals depending upon them. By July 20 the high prairies adjacent to the Boise and Saw Tooth mountains, the home of numerous herds of cattle, horses, and sheep were becoming dry, except for a few springs long distances apart, and glacial deposits in the Saw Tooth range that had been in existence from time immemorial, disappeared or dwindled into insignificance by midsummer. There was general suffering in many communities owing to lack of water. Streams of moderate size, which had supplied sufficient water for irrigation in previous years were entirely dry by midsummer, and it was necessary for herders to abandon good pasture for the purpose of securing water.

It was fortunate that the plan of securing snow records was inaugurated, since the bulletins issued during the winter of 1899–1900 will continue to form the base of reasoning for many years in determining the probable water supply.

Tabulated statement from the March bulletin showing condition of snow in Idaho on March 31, 1900.

Station.	County.	Compared with average.	Amount on ground.	At timber line.	At or near summit of mountains.	Prospective water flow.
Snake River watershed.		*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
Afton	Wyoming	......	0	......	40	......
Bedford	....do	—	8	......	24	......
Blackfoot	Bingham	—	0	0	12	—
Bryan	....do	—	0	2	12	—
Coltman	....do	—	0	?		—
Grover	Wyoming	......	3	......	36	......
Hatch	Bannock	—	0	0	36	—
Houston	Custer	—	0	24	36	—
Howe	Blaine	—	0	8	10	—
Idaho Falls	Bingham	—	0	0	trace	—
Labelle	Fremont	—	0	6	36	—
Lago	....do	—	0	30	36	—
Lost River	Blaine	—	0	6	18	—
McCammon	Bannock	—	0	......	4	—
Oxford	....do	—	0	12	48	—
Presto	Bingham	—	0	0	12	—
Rexburg	Fremont	—	0	0	?	—
Sarilda	....do	—	0	0	6	—
Thayne	Wyoming	......	0	......	8	......
Wilford	Fremont	—	T.	66	72	—
Bear River and lake drainage.						
Clifton	Oneida	—	0	3	24	
Fairview	....do	—	0	12-20	48	—
Georgetown	Bear Lake	—	0	30	?	—
Mink Creek	Oneida	—	0	6	36	—
Ovid	Bear Lake	—	0	24	60	......
St. Charles	....do	—	2	12	?	aver.
Wood River.						
Bellevue	Blaine	—	0	0	drifts	—
Ketchum	....do	—	0	12	24	—
Corral	....do	—	0	14	24	—
Boise basin.						
Centerville	Boise	—	0	drifts	30	—
Placerville	....do	—	0	?	36	—
Owyhee Mountains.						
De Lamar	Owyhee	—	0	24	few ins	—
Sinker	....do	—	0	18	18	—
Salmon River.						
Florence	Idaho	—	48	60	120	—
Mount Idaho	....do	—	0	0	48-192	—
Salmon City	Lemhi	—	0	24-36	36-60	—
Shoup	....do	—	0	aver.	aver.	—
Columbia River watershed.						
Bellgrove	Kootenai	—	0	?	......	—
Burke	Shoshone	—	T.	96-120	120-174	—
Bonners Ferry	Kootenai	—	0	......	120-144	—
Kamiah	....do	—	0	......	48	—
Hope	....do	—	0	0	18	—
Kingston	Shoshone	—	0	2	24	—
Kootenai	Kootenai	—	12	36	72	—
Rathdrum	....do	—	0	0	24	—
Santa	....do	—	0	drifts	12	—

NOTE.—The dash (—) is used where fall has been less than average or where prospective water flow is likely to be less.

MONTANA.

By E. J. GLASS, Special Director.

Montana is drained by three large rivers, the Missouri and Yellowstone on the east, and Clarkes Fork of the Columbia River on the west side of the Rocky Mountains. All the tributaries of these three rivers rise in the mountains, and derive their water supply from the melting of snow that has been stored there during the winter and spring months. By having a knowledge of the depth, character, and distribution of the snow that has accumulated during the months of January, February, and March, a reliable general forecast of the water supply for the ensuing season can be made for the different streams of the State. There is one element that enters into the forecast that can not at present be foreseen, and that is, a knowledge of temperature. This, however, affects the water flow only in the early spring, commonly known as spring freshets, which occur in April, May, or June.

In the mountains of Montana there are hundreds of canyons and ravines where the sun shines but little, if any, during the day. These deep ravines are the storage places of the water supply. This is an example of nature's economical distribution of her supplies for man's use. High winds drift the snow into these storage places to a great depth, where, by its own weight, aided by the changes in temperature, it gradually solidifies, in which condition it loses little from evaporation and yields its moisture but slowly and during a comparatively long period during the later spring and early summer. Drifts are also formed at the bases of precipitous cliffs, which, if located on the northern slope of mountains or hills, remain until May or June before they entirely disappear, and greatly assist in maintaining a steady flow of water in springs and small streams.

Accurate knowledge of the depth of snow in the valleys and foothills, in the mountains both above and below the timber line, in ravines, deep canyons, and at the bases of cliffs and precipitous bluffs are all essential in making an accurate forecast of the amount of water in streams during the spring and summer months.

The volume of water in the mountain streams and creeks during the spring freshets that come with the first warm weather of April or May, depends on the depth of snow in the valleys and the foothills. The high water in the larger rivers, occurring during the first protracted warm weather in May or June, is determined by the depth of accumulated snow in the mountains both above and below the timber line. The drifts in the ravines and canyons remain to furnish the steady flow to the streams during the summer months. The temperature and weather are important factors in the spring freshets and floods. Continued warm weather and warm rains greatly augment the flood stages, while warm weather followed by a sudden fall in temperature will greatly lessen the chances of floods, as the slush snow, being frozen, melts more slowly afterwards.

At the beginning of the year 1900 the Montana section of the climate and crop service published, by direction of the Chief of the Weather Bureau, three special snow bulletins, dated January 31, February 28, and March 31. These special bulletins were made up of reports received from 294 correspondents situated in every portion of the State. The greater number of correspondents, however, were in the mountain districts, and gave very valuable information as to the depth of snow in drifts, ravines, and in the mountains both below and above the timber line. These three bulletins each told the same story: "The least snowfall in the mountains that has occurred for many years past." Drifts were of unusually small dimensions, and in many ravines, where snow in former years accumulated to a depth of from 20 to 50 feet, this year there was practically none. The lack of drifts was due to calm weather, there having been no high winds immediately following snow storms. The hills were practically bare and cattle grazed in the valleys all winter. The mild weather during the winter months, aided by chinook winds, caused the south side of the mountains to be free from snow, while many mountain streams were bank full during the winter months. The correspondent at Ovando, situated on the main range of the Rocky Mountains in Deer Lodge County, under date of April 5, 1900, writes:

> All ravines running north and south on the southern side of the mountains are almost bare of snow up to the timber line. These same canyons were covered with snow during 1899 until July 1. There is less snow on the ground now than at this season in any year during the past ten.

The snow bulletins were of great importance to the mining, stock, and agricultural interests; and all interested persons were informed that the water supply in the streams would be greatly reduced and that no spring floods would occur. The deficiency of the water supply in the streams of the State was made very apparent by the facts contained in the snow bulletins.

On April 17 the first issue of the weekly climate and crop bulletin for the growing season of 1900 appeared. Reports in the crop bulletin dated May 15 contain several references to the water supply, this being the usual time for high water to occur. Reports received from Dawson County stated that many small streams were drying up. Reports from Deer Lodge County stated that creeks were very low for that season of the year, while Gallatin correspondents reported West Gallatin River, bank full from the effect of the rapid melting of the snow in the mountains. Streams in the Bitter Root Valley were bank full, while Kootenai and Red Rock rivers were quite low. Every crop bulletin issued after the above date (May 15) contained reports from different localities that springs and streams were drying up and that rivers were very low.

No river in the State overflowed its banks from the melting of snow during the first warm weather periods, and in June all the snow had disappeared from the mountains except a very few small drifts in the deep ravines and canyons. As a result of the deficiency of storage snow, as shown by the snow bulletins, springs became dry that had never been dry before, and the water supply of small streams failed, compelling cattle to travel long distances for water. Many farmers were deprived of water for irrigation purposes, the entire supply of many streams being exhausted by water rights owned by ranchmen living near the head waters. During ordinary years the flow of water had been sufficient for both.

The meteorological conditions during the time covered by the snow bulletins and weekly crop bulletins show the highest mean temperature on record for January and March and an excess of temperature for January, March, April, May, and June, and a deficiency during February, August, and September. The precipitation was deficient for January, February, June, and July, while an excess is recorded for March, April, May, August, and September. The greatest departures from the normal precipitation were a deficiency of 1.89 inches for June and an excess of 1.15 inches for April. The rainy season occurred in April of this year, instead of the latter part of May or in June, as it commonly does.

The importance of having accurate reports of the depth of snow on the mountains is very emphatic, as the observations taken by voluntary observers in the valleys do not give *all* the facts necessary for the intelligent preparation of a seasonal forecast of the water supply for a given section.

NEW MEXICO.

By R. M. HARDINGE, Section Director.

The snowfall bulletin issued from the New Mexico section center at Santa Fe on the 3rd of March stated:

> The total snowfall thus far for the winter was much less than usual. There is an absence of the large drifts from which comes the greater part of the spring flow. At the headwaters of the Rio Grande and San Juan rivers, in southwestern Colorado, there seems to be about the average amount of snow, but from their New Mexico tributaries these streams will receive very little increase unless conditions change. Of the streams whose watersheds lie wholly within New Mexico it is safe to say that the present snow supply is not enough to keep up the current flow, and unless there is heavy snow soon or good early rains the sections depending on these are threatened with a serious water famine in the early spring.

The 1st of April found little water in the streams, excepting the Rio Grande, and there was no prospects for a continuous supply from the mountain sources. General storms on the 6th, 7th, and 8th of April, bringing rain and snow to the lowlands, and a good fall of snow on the mountains of Colorado and northern New Mexico, entirely changed the water prospect, especially for our local streams. A second snowfall bulletin, issued on April 13, gave the information that, although the snow of these storms quickly disappeared from the lowlands, it had helped the streams, and predicted that in connection with the steady supply that could now be expected from the mountain sources a fair supply of water in the streams was practically assured for some time to come. In conclusion this bulletin stated:

As there is an absence of the usual hard-packed drifts in the mountains, there is a likelihood of this source of supply being exhausted in a few weeks, but if augmented by the normal precipitation of this season of the year it is thought that the water flow will be fairly sufficient until the summer rains begin.

This forecast was verified, as there was no scarcity of water in those sections which received a seasonal and normal rainfall.

As a rule the water supply of the streams in the Territory was sufficient for the lands under ditch during the growing season, with the exception of the lower Rio Grande, and lands in the northern counties of Taos and Rio Arriba, which depended on small local streams. Approximately the upper half of the Rio Grande had normal volume beginning early in March, but the flood water rapidly diminished from Socorro southward, because of use and seepage, and did not arrive at the southern boundary of the Territory until the middle of May. From that time on there was a fair supply of water in the Rio Grande throughout its course in New Mexico.

The San Juan River, running to the westward through the extreme northwestern part of the Territory, and drawing its supply almost exclusively from the mountains of southwestern Colorado, furnished sufficient irrigation water throughout the season, although there was almost a total absence of the usual summer rains over that part of its watershed lying in New Mexico.

The Gila and San Francisco rivers, draining the southwestern counties and, like the San Juan, carrying their waters westward of the Continental Divide and through Arizona, had less than their usual flow during the greater part of the season. As a rule, however, they carried sufficient water for the ditches lying in New Mexico.

Over the western half of the Territory, affecting the sources of the Gila and San Francisco rivers and so much of the watersheds of the San Juan and Rio Grande as lie within New Mexico, there was a marked deficiency in the usual winter, spring, and summer precipitation. Even the normally rainy months of July and August were wholly lacking in general showers. The crops of this section which depend on direct rainfall for moisture were almost total failures, and the ranges were so dry that stockmen generally made arrangements to move the flocks and herds to eastern plains. Notwithstanding this disastrous drought in the lower valleys and plains, there were frequent thunderstorms in the vicinity, but their limits were confined to the highest mountain peaks; yet the water furnished from that source was sufficient to supply the irrigated districts fairly well throughout the drought. Ordinarily the rainy season is drawing to a close by the end of August, but this year during the first decade of September there occurred general and heavy rains—torrential and damaging in localities—and the drought conditions for this section were entirely relieved for the remainder of the season.

Over the eastern half of the Territory, embracing the watersheds of the Pecos and the upper Canadian rivers, the conditions were quite different. This whole section, especially in the northeast during the earlier months and the southeast during the later, received a surplus of precipitation almost as marked as was the deficiency in the west. Excepting some local and minor streams of the middle east, these rivers had an abundant flow throughout the season.

UTAH.

By L. H. MURDOCH, Section Director.

In mountainous countries where irrigation is practised and in sections where fall grain is raised, in the temperate zone of the Northern Hemisphere, a study of the water supply from September to August, inclusive, is undoubtedly most instructive. With the exception of a few minor products the crops of a season are matured by the close of August. The rains of September place the fields in condition to be worked and to germinate fall sown grain. In irrigation districts the growth and maturing of the crop of the following season will depend almost entirely upon the supply of water that is received from the snow accumulated in the mountains from October to April. For the foregoing reasons the year used in this article will be from September to August, inclusive.

Precipitation of the year 1899–1900.—September was the driest since the establishment of the Utah section of the climate and crop service in 1891. The average precipitation for the State was only 0.05 inch, or 0.78 inch below the normal. The precipitation was all in the form of rain. The normal snowfall for September is 0.4 inch.

October was unusually wet, the average precipitation being 1.46 inches, or 0.59 inch above the normal. The average depth of snowfall was 3.2 inches, or 1.9 inches above the normal.

The average precipitation for November was 0.70 inch, or 0.13 inch below the normal. The snowfall was unusually light and was confined exclusively to the mountains; the average was only 0.6 inch, or 4.8 inches below the normal.

The average precipitation for December was 0.95 inch, or 0.04 inch below the normal. The snowfall amounted to 8.2 inches, which was 4.5 inches above the normal.

The Utah records do not show a drier January than that for 1900. The average precipitation was 0.43 inch, or 0.73 inch below the normal. The average snowfall was 2.1 inches, or 8.6 inches below the normal.

February was also a very dry month. The average precipitation was 0.57 inch, or 0.65 inch below the normal. The average snowfall was 5.1 inches, or 4.4 inches below the normal.

Following the directions of the Chief of the United States Weather Bureau, a snowfall bulletin was published, beginning with the month of February. This bulletin gives the depth of snow on the ground, depth on mountains or hills, compares depth with that of same month of preceding year and with the average, and gives the prospective water supply. The following is the summary of the February bulletin:

At the close of February there was no snow in the valleys except in Summit, Rich, and portions of Cache, Morgan, and Wasatch counties. The winter's snowfall has been very much below the average—less than for a number of years. Most of the snow in the mountains and hills fell during February, and is not packed as it would be had it fallen earlier in the season. On an average the snowfall in the mountains is only about half that of last year, and less than three-fourths of the usual amount. With the exception of localities in Boxelder, Cache, Rich, Weber, and Davis counties, the prospective water supply is far below the average.

March was the driest on record and probably the driest in the history of the State. The average precipitation was 0.19 inch, or 1.41 inches below the normal. The average snowfall was 1.2 inches, or 8.2 inches below the normal. The following is the summary of the snowfall bulletin issued for March:

The snowfall during March was confined to Cache, Rich, Weber, Morgan, Davis, Salt Lake, Summit, Tooele, Sanpete, Sevier, Wayne, and Garfield counties. In these counties the fall was unusually light, ranging from less than an inch to four inches, with the exception of 12 inches in Piute County. Nearly all of the snow which fell came with the storm of March 4 and 5, and disappeared from the valleys within a few hours. The month was unusually warm, as well as unusually dry, which caused rapid melting of the already scant supply of snow in the mountains. At the close of March the depth of snow in the mountains was not more than one-half the average amount. Many reporters state that the past winter was the driest they have ever known. The water supply will be very short, and many localities will have to depend largely upon spring and summer rains to carry the crops through to maturity.

The precipitation for April amounted to 2.46 inches, or 1.51 inches above the normal. The average snowfall was 7.1 inches, or 3.9 inches above the normal.

A drought began with May and lasted the remainder of the season. The average precipitation for May was 0.36 inch, or 0.84 inch below the normal; for June, 0.16 inch, or 0.27 inch below normal; for July, 0.09 inch, or 0.56 inch below normal, and for August, 0.34 inch, or 0.31 inch below normal. The normal snowfall for May is 1.7 inches, but practically no snow fell after April.

Summary and comparisons.—The average precipitation for the State for the year ending August 31, 1900, was 7.76 inches, or 3.62 inches below the normal. The average snowfall was 27.5 inches, or 17.8 inches below the normal. It was the driest year since 1888–89, the precipitation for the years 1887–88, 1888–89, and 1899–1900 being about the same. The accumulated snow in the mountains at the opening of the summer was less than the season's fall in the valleys would indicate, for two reasons. Firstly, in an ordinary season frequent snowstorms occur in the mountains that do not reach the valleys, while during the season of 1899–1900 there was nearly an entire absence of local snowstorms in the mountains. Secondly, the season was exceptionally warm, which allowed much melting.

Results.—The heavy rainfall of April gave the crops a good start and made the use of irrigation water unnecessary at that time. As shown by the record, an unusually dry spell began with May and lasted the remainder of the season. As predicted in the snowfall bulletin for March, irrigation water was very short and had to be used with the utmost economy. By the middle of June, with the exception of a few localities, the supply began to fail and was not sufficient to meet the demands. Some of the higher lands, which had been watered in former seasons, received no water at all. Water was used for the most important crops, while the less important and most hardy ones were allowed to depend largely upon the rainfall. As a result of this, several crops gave yields more or less below the average. The localities having plenty of water throughout the season were those supplied from reservoirs and about 20,000 acres in Boxelder County supplied from the Bear River Canal.

Old residents on the Colorado, Bear, and Provo rivers state that these rivers were lower during August and September of 1900 than ever known before. The other rivers and streams of the State were very low at the same time, and many of them reached low water mark.

In Salt Lake City great economy was exercised in the use of water from the pipes. The supply began to fail in July, and during August and September the shortage amounted to 3,000,000 gallons per day. On account of this emergency the city sold $250,000 of bonds to secure money with which to deepen the Utah Lake Canal, buy new water rights and make other improvements in the waterworks department.

The level of Utah Lake dropped to 3 inches above what is known as low water line, but the level in October of 1889 was about 13 inches lower. The level of Great Lake dropped to 8 inches below the zero of the gage, breaking the record by 20 inches, the previous lowest recorded level, 1 foot, was reached near the close of 1860.

Snowfall bulletins of the Weather Bureau.—The past season has emphasized the value of the snowfall bulletins, and they will, hereafter, be one of the most popular publications of the Weather Bureau. The data contained in the bulletin for March, showed plainly that there would be a decided shortage in the water supply, notwithstanding the fact that no similar data were on file for use in making comparisons. The bulletins will be published for the months of December, January, February, and March. Their value will increase with the accumulation of the data which they contain, and farmers, stockmen, superintendents of waterworks, officials of canal companies, etc., will study them closely and regulate their affairs accordingly.

WYOMING.

By W. S. PALMER, Section Director.

The past season in Wyoming was unusually dry over many sections of the State, especially over the southwestern and northeastern counties; in southeastern Wyoming, that is, in Laramie and Albany counties, the deficiency in precipitation was not so marked as over the sections previously named, and the streams of the Laramie and Platte watershed in southeastern Wyoming maintained their flow much later than the streams of the Green River watershed in southwestern Wyoming or the streams on the eastern slope of the Big Horn Mountains in northeastern Wyoming. As many of the streams of the State are fed by the melting snow from the mountains, a review of the conditions existing over the State during last winter is necessary in order to fully understand why so many streams failed in the early summer.

The following table, compiled from the records of about thirty stations in Wyoming, shows the average monthly precipitation for each month from November to August, inclusive:

Month and year.	Average precipitation.	Departure.	Month and year.	Average precipitation.	Departure.
November, 1899	0.13	−0.56	April, 1900	4.46	+2.68
December, 1899	0.69	+0.02	May, 1900	0.59	−1.29
January, 1900	0.23	−0.46	June, 1900	0.47	−1.07
February, 1900	0.90	+0.14	July, 1900	1.22	+0.07
March 1900	0.44	−0.97	August, 1900	0.37	−0.45

The stations from which these records were obtained are situated at elevations ranging from 3,500 feet to 8,800 feet, and while the figures may not represent the actual average precipitation in the mountains, the monthly departures will give some idea as to whether an excess or a deficiency of precipitation occurred over the mountain districts, as the records available for comparison show that a deficient precipitation at the lower elevations means a deficient snowfall on the mountains. It can be seen from the table that the months of November, January, and March gave decided deficiencies, and the months of December and February but slight excesses. During five months from November to March, inclusive, the months during which the stock of snow in the mountains usually accumulates and packs solid for the water supply of late summer, Wyoming received an accumulated precipitation of but 2.39 inches, or only about one-half of the usual precipitation, the normal for the five months being 4.32 inches.

The precipitation during April was unusually heavy over nearly all portions of the State, but the snow which fell in the mountains melted very early in the season. Snow which falls in the mountains during April or May can not be depended on to supply water for late summer irrigation, and the stock of snow which fell in the mountains last April melted very early in the summer, due to the usually warm weather of May and June, the temperature for the two months in the State averaging from 4° to 6° per day above the normal.

The precipitation during May, June, and August, was very deficient throughout the State, and during July it was but slightly in excess of the normal. Of the ten months, six were decidedly deficient in precipitation, three months but slightly in excess of the normal, and but one month, April, had a decided excess.

It might be remarked in this connection that the season in Wyoming was a fairly successful one to the agriculturist, as the heavy precipitation of April was especially favorable to the meadows of the State, and despite the adverse conditions of May and June, a crop of hay probably in excess of the average was harvested; it may be safely said that the value of the hay crop, native and alfalfa, exceeds that of all other agricultural and garden products raised in this State at present.

At the close of the months of January, February, and March, 1900, special snowfall bulletins, based on reports of reliable correspondents in various portions of the State, were issued from the Weather Bureau office at Cheyenne. These bulletins showed that much less snow than usual had accumulated in the mountains in nearly all portions of the State. In the report issued about the 10th of April it was predicted that a flow of water less than the usual would prevail in the streams of the State during the summer. Owing to the very small stock of snow in the Big Horn Mountains, it was predicted that a decided shortage of water would occur in the streams on the eastern slope of the Big Horn Mountains; this prediction was fully verified, for by the last of June water was very low at Sheridan, and only the early appropriators could secure water for irrigation; by July 6 low water was reached at Parkman, Sheridan County; on August 15 the Powder River at Griggs was the lowest it had been for years. Owing to the light snowfall of the winter and continued dry weather in early summer, the streams of the Green River watershed dried up very early in summer. Over the Laramie and Platte watershed, where a fair stock of snow existed at the close of March, as shown by the snowfall bulletin for that month, the flow of water in the streams was maintained much later than in other sections, although the amount of water was less than usual in nearly all the streams of the State. The gaging station, maintained by the United States Geological Survey, at Woods on the Laramie, a station above nearly all of the ditches on that stream, showed that high water was reached as early as May 30, 1900, while during 1899 high water was not reached till June 25; the flow of water at that station in August, 1900, was much less than the flow in September, 1899.

The interest and value of these monthly snowfall bulletins has been such that the Chief of Bureau has authorized their issue for Wyoming during the coming winter, when it is hoped to make them of even more interest and value than during the past winter. It is expected that special snowfall bulletins for Wyoming will be issued at the close of the months of December, January, February, and March.

TORNADOES IN TENNESSEE, MISSISSIPPI, AND ARKANSAS.

By S. C. EMERY, Local Forecast Official, dated November 20, 1900.

During the afternoon and evening of November 20, 1900, the section of country embracing southeastern Arkansas, northern Mississippi, and western Tennessee was visited by at least six distinct tornadoes, all of which were destructive and exhibited the usual characteristics of such storms. All moved in exactly the same direction in parallel lines, with a rate of progressive motion of from 45 to 60 miles an hour, as shown in fig. 3.

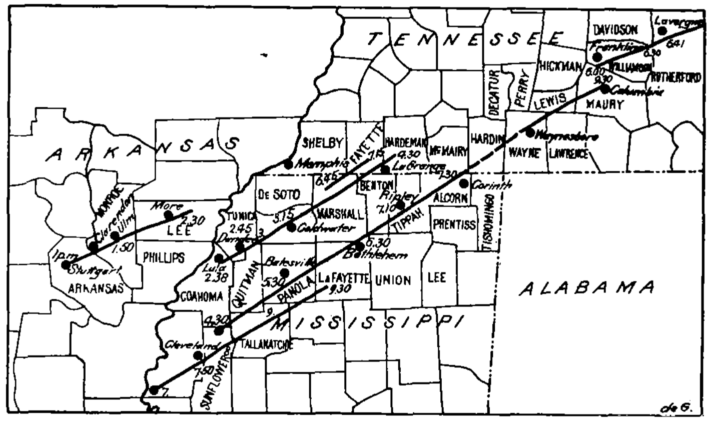

FIG. 3.—Tracks of tornadoes, November 20, 1900.

Some portions of the country through which the tornadoes moved are thickly settled, and as everything within the limits of their narrow paths was destroyed, the loss of life and property was very severe. The actual deaths resulting from these storms number at least seventy-three, while a large number of persons were seriously injured and a much greater number rendered homeless by the destruction of their dwellings. Through the farming districts the loss was mainly confined to fences, farm buildings, and negro cabins, a great number of the latter being carried completely away. Unpicked cotton was stripped from the stalk and scattered broadcast over the country, and instances were noted where large quantities of cotton were carried by the tornado to distant forests and deposited upon trees making them appear to be covered with snow.

Correspondents along the tracks of the storms report a funnel-shaped cloud; some liken its appearance to a balloon, others to a haystack, while some speak of it as a very black or greenish cloud with a small twisting end touching the earth. In some places the cloud appeared as a great ball of fire, and at others small balls of fire shot out of the lower portion of the cloud. The most notable feature, and the one mentioned by all who observed the storms, was the intense and constant lightning, the extreme brilliancy of which in some cases turned night into day. The noise attending the passage of the storm cloud is generally described as a deep roar like the moving of many railway trains, which could be heard for some time before the storm arrived. The warning thus given enabled many to seek places of greater safety and was the means of saving life. Hail is reported in only one or two instances. Generally, after the tornado had passed, heavy rain set in which continued for some time.

One fact worthy of note is that through the low, timbered sections the path of destruction was much narrower than over the high ground, though in both cases there appears to have been nothing in the way of buildings or trees sufficient to resist the wind. The weather conditions during the morning of November 20, throughout the section affected, were exceedingly threatening. Temperature was abnormally high for the season, air close and sultry, and for several hours a general feeling of oppression prevailed. Frequent showers of short duration occurred, usually accompanied by thunder and sudden gusts of wind. Heavy rain would start in and continue for five minutes or less, and then end as abruptly as it began. Wind fresh from south and southwest until about noon, when it died down to nearly a calm. The barometer at Memphis, Tenn., rose slightly during the morning, but